A Novel Approach for Multi-Dimensional Variable Sized Virtual Machine Allocation and Migration at Cloud Data Center

Neeraj Kumar Sharma
Department of Information Technology
National Institute of Technology Karnataka
Surathkal, Mangalore India
neeraj16ks@gmail.com

G. Ram Mohana Reddy
Department of Information Technology
National Institute of Technology Karnataka
Surathkal, Mangalore India
profgrmreddy@gmail.com

***Abstract*—In this paper, we propose a branch-and-bound based exact algorithm for allocating multi-dimensional variable sized VMs at the cloud data center. Further, an energy efficient VMs migration technique is proposed to reduce the energy consumption and thus avoids the Service Level Agreement (SLA) violation at the cloud data center.**

I. Introduction and Related Work

In this paper, we propose the branch-and-bound based exact algorithm for solving the multi-dimensional variable size VMs allocation in heterogeneous data center environment. In this approach, the root node of the search tree initially contains the empty solution. Further, the child node in the search tree is created when a new PM is used for the allocation of VMs. Each child node of the search tree contains the partial solution of the VMs allocation problem. Then we apply the First-Fit-Decreasing (FFD) algorithm for migrating the VMs from the underutilized (idle) PMs to the energy efficient PMs resulting in switching-off underutilized PMs.

There are several state-of-the-art works on VMs allocation problem. A. Beloglazav et al. [1] proposed a modified Best-Fit Decreasing (MBFD) algorithm for VMs allocation at the homogeneous data center environment. A. Xiong et al. S. Wang et al. [2] suggested a Particle Swarm Optimization (PSO) based energy efficient VMs allocation in the homogeneous data center environment. But a very less amount of work is done on variable size VMs allocation problem in heterogeneous data center environment.

II. Proposed Approach

A. VMs Allocation The power consumption (P_k) of a physical machine (pm_k) at the data center is given by

$$P_j = ([P_k^{max} - P_k^{min}])u + P_k^{idle}. \tag{1}$$

Where P_k^{max} and P_k^{min} are the maximum and minimum power consumptions of a pm_k, respectively; u is the rate of CPU utilization ($0 \leq u \leq 1$)*.* Let us consider a data center with a set of m types of PMs and n number of VMs. The dimensions of pm_k are defined as MIPS (pm_k^{MIPS}), RAM (pm_k^{RAM}), Processing elements (pm_k^{PE}), and Storage ($pm_k^{STORAGE}$), respectively. Further, the dimensions of vm_i are mips (vm_i^{mips}), ram (vm_i^{ram}), processing elements (vm_i^{pe}) and storage ($vm_i^{storage}$), respectively. Let $pm_{max}^{MIPS} = max_{k\in\{1,2,\ldots m'\}} pm_k^{MIPS}$, $pm_{max}^{RAM} = max_{K\in\{1,2,\ldots m'\}} pm_k^{RAM}$,and $pm_{max}^{Storage} = max_{K\in\{1,2,\ldots m'\}} pm_k^{Storage}$ be the maximum MIPS, RAM, and Storage of maximum PM, respectively at the data center. The Integer Linear Programming (ILP) based multi-dimensional VMs allocation to PMs problem in the binary form can be formulated as follows:

$$min \quad p = \sum_{k=1}^{m'} P_k z_k \tag{2}$$

Subject to the following constraints:

$$l_{ij} + l_{ji} + b_{ij} + b_{ji} + (1 - f_{ik}) + (1 - f_{jk}) \geq 1, \quad i,j \in \{1,2,..,n\}, k \in \{1,2,..,m'\}, i < j \tag{3}$$

$$x_i - x_j + pm_{max}^{MIPS} l_{ij} \leq pm_{max}^{MIPS} - vm_i^{mips}, \quad i,j \in \{1,2,..,n\}, k \in \{1,2,..m'\} \tag{4}$$

$$y_i - y_j + pm_{max}^{RAM} b - ij \leq pm_{max}^{Storage} - vm_i^{storage}, \quad i,j \in \{1,2,..n\} \tag{5}$$

$$x_i \leq pm_k^{MIPS} - vm_i^{mips} + (1 - f_{ik}) pm_{max}^{MIPS}, \quad i,j \in \{1,2,..,n\} \tag{6}$$

$$y_i \leq pm_k^{RAM} - vm_i^{ram} + (1 - f_{ik}) pm_{max}^{RAM}, \quad i,j \in \{1,2,..,n\} \tag{7}$$

$$\sum_{k=1}^{m'} f_{ik} \geq 1, \quad , k \in \{1,2,..m'\} \tag{8}$$

Where variable l_{ij} is 1 if vm_i is allocated left to vm_j; l_{ji} is 1 if vm_j is allocated left to vm_i b_{ij} is 1 if vm_i is below to vm_j; b_{ji} is 1 if vm_j is below to vm_i; The binary variable f_{ik} value 1 if vm_i is allocated to pm_k; The binary variable z_k is 1 if pm_k is used for VMs allocation; (x_i, y_i) are the lower left coordinates of vm_i. For the allocation of n number of VMs, we can not use more than n number of PMs of any type.

978-1-5090-4250-0/17/$31.00

Thus the binary version of VMs allocation problem consists of $m' = mn$ separate number of PMs at the data center.

The lower bound R_L of the VMs allocation to PMs problem is described by the Eq. 9

$$R_L = inf_{I \in p}\{\frac{L(I)}{OPT(I)}\} \tag{9}$$

Where p is the set of all instances of VMs allocated to PMs; L(I) is the objective value in the terms of energy efficiency is given by Eq. 2 for an instance I; OPT(I) is the optimal objective value for instance I.

To calculate the optimal allocation of VMs to PMs, the following data is associated with each node N at the level l of the search tree such as: a lower bound $LB(N)$, an upper bound $UB(N)$, and the partial solution.

$S'(N)$: is a subset of unallocated user requested VMs such as ($|S'(N)| = n - l$); $v_k(N)$: is the number of PMs of type k that have been already used at the data center for the allocation of VMs; $v(N)$: is the total number of PMs of all types that have been already used for the allocation of VMs at the data center such as ($v(N) = \sum_{k=1}^{m} v_k(N)$); $p(N)$: is the sum of power consumption of all the PMs that have been already used for the VMs allocation such as ($p(N) = \sum_{k=1}^{m} v_k(N)p_k$).

The root node N_0 in the search tree contains (empty solution) and other nodes at level $l \geq 1$ consist of the partial solution (a subset of VMs allocated to PMs) at the data center. A child node in the search tree is created by allocating the largest VM in the VMs list to an already initialized PM (used PM) or to an empty PM (unused PM) of type k. Therefore, a node N in the search tree may consist of maximum number of child nodes ($m + v(N)$). A child node N^+ of a given node N in the search tree space, corresponding to allocating vm_i into a PM of type k is created if and only if the following conditions are satisfied:

(i) (C_1) $v(N) \leq v^u$ (v^u is an upper bound for the total number of PMs are used in an optimal solution for the allocation of VMs to PMs at the data center);

(ii) (C_2) $v_k(N) < v_k^u$ (v_k^u is an upper bound for the number of PMs of type k that are used in an optimal solution for the allocation of VMs);

(iii) (C_3) $c(N) + c_K < ub(N)$;

(vi) (C_4) $d_i \leq D_k$, $\forall d \in \{mips, ram, storage\}$ or $d_i \leq D_K$ if k is initialized PM;

Hence, if the above defined conditions are met, then the lower bound value $lb(N^+)$ is computed. Further, if $lb(N^+) \geq ub(N)$ then the child node is pruned from the search tree.

B. VMs Migration Let us consider a set of already used PMs s, $|s| < m'$ at the data center. The objective function for VM migration at the data center is defined as.

$$max \quad y = \sum_{i \in s} P_i^{min} y_i - \sum_{i \in s} \sum_{j \in s} \sum_{k=1}^{n_i} P'_K z_{ijk}. \tag{10}$$

Where y_i=1 if pm_i is used for allocation of VMs, otherwise $y_i = 0$; The binary variable z_{ijk}=1 if vm_k migrates from pm_i to pm_j otherwise z_{ijk}=0; P'_K is the power consumption of virtual machine vm_k; n_i is a set of VMs to be migrated from pm_i to energy efficient PMs. The VMs migration constraints are defined as

$$\sum_{i \in s} \sum_{k=1}^{n_i} vm_k^d z_{ijk} \leq pm_j^d (1 - y_j) \tag{11}$$

$$\sum_{j \in s} \sum_{k=1}^{n_i} z_{ijk} = n_i y_i \quad \forall i \in s, i \neq j \tag{12}$$

The migration of all the VMs from pm_i to pm_j will take place if the following conditions hold good:

i)The present CPU utilization of pm_i is less than the defined lower threshold value u_l of pm_i such as ($u_j^{cpu} < u_l$).

ii) The migration cost for all the VMs allocated to pm_i should be less than the rent of VMs as decided by the cloud service provider during the left over time t_l.

III. EXPERIMENTAL RESULTS AND ANALYSIS

To create the heterogeneous data center, we consider 300 PMs of different types i.e. 300(100,100, 100), and four different amazon EC2 VMs instances i.e. (small, medium, large, and x.large). Table I gives the details of number of VMs, type of VMs and duration of VMs requested by different users during different time instances. The energy consumption of proposed approach on different time instances of heterogeneous data center is compared with state-of-the-art approximation algorithms such as Best-Fit, First-Fit, Modified-First-Fit-decreasing and the results are shown in Fig. 1.

TABLE I: VMs Requested

User	Small	Medium	Large	X.large	Time duration
User1	80	70	50	50	0 to 50
User2	70	50	40	60	40 to 100
User3	50	30	40	95	80 to 150
User4	65	70	80	100	140 to 250

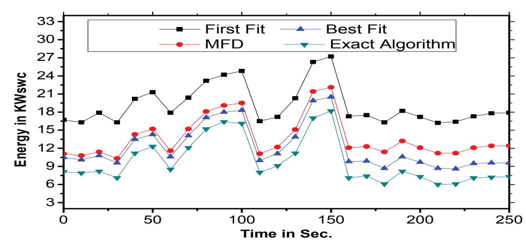

Fig. 1: Energy Consumption at Heterogeneous Data Center

IV. CONCLUSION AND FUTURE WORK

The proposed approach for VMs allocation saves 6-8 % of the energy consumption when compared to that of the Best-fit at the heterogeneous data center. The saving of energy consumption of networking elements such as routers and switches will be considered in near future.

REFERENCES

[1] M. LLC. (2008) ”report to congress on server and data center energy efficiency: Public law 109-431”,berkeley lab., ca, usa, lbnl-363e.

[2] D. Boru, D. Kliazovich, F. Granelli, P. Bouvry, and A. Y. Zomaya, “Energy-efficient data replication in cloud computing datacenters,” *Cluster Computing*, vol. 18, no. 1, pp. 385–402, Mar. 2015. [Online]. Available: http://dx.doi.org/10.1007/s10586-014-0404-x